Communicating Antarctic Climate Science

PCAS Syndicate Project Report

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Table of Contents

Abstract

Many societal-political aspects of climate change act as barriers to positive climate change action. Despite the efforts of scientific researchers, stakeholders and the media, effective and accurate communication of Antarctic science is below an acceptable standard. The findings and implications of high-quality Antarctic climate change science are failing to resonate with civil society and policy makers, dictating the need to re-evaluate how members of society cognitively approach the contentious issue of climate change and how current Antarctic science communication resources are distributed. An individual's worldview, cognitive mindset and religious dogmas in conjunction with misreporting and misinterpretation of climate science are all factors influencing how an individual responds to the climate change message but rarely have they been analysed together as a complete overview. In this report, we introduce a new approach, advising that climate scientists, policy makers and other relevant stakeholders are involved in all stages of science acquisition, legislation and decision making through a targeted boundary committee, strongly integrated with a thorough education, outreach and communication (EOC) approach, within SCAR, and tasked with communicating Antarctic science and its global teleconnections. We draw on the barriers identified through literature investigation to establish this recommendation. The incorporation of a strong EOC approach in climate science communication will provide the catalyst required for substantial climate change action.

Background

From the late 20th century to the early 21st century, the prominent environmental and socio-political issue of climate change has risen to the forefront of popular debate. The Intergovernmental Panel on Climate Change has stated with 95% confidence that human activity is the dominant cause of observed changes in global temperatures since the mid-20th century (Solomon et al., 2007). Increases in air and ocean temperatures, rising sea levels and large-scale snow and ice melt have been observed throughout the world, along with changes to intensity and frequency in extreme weather and climate events, underlining the presence of anthropogenic climate forcing in our world today (Solomon et al., 2007). The Earth's climate is a dynamic, non-linear system, requiring astute comprehension of its constituent biological, chemical and physical components before the future impacts of global climate change can be properly understood (Schneider, 2004). Earth system science integrates research from numerous academic disciplines to view the Earth as a progressive system, which in turn provides a physical framework to understand the world (Kennicutt II, 2014). In order to reduce uncertainty about aspects of the climate system, there is a distinct need for global observation systems to provide long-term climatological and environmental observation datasets for palaeoclimate model verification and future projections; however as yet, only fractions of it exist (Karl & Trenberth, 2003).

Antarctica is of global environmental, political and scientific significance. It is governed through a complex system of international legal agreements, entitled the Antarctic Treaty System, which has designated Antarctica as a continent for the purposes of peace and science (Joyner, 1998). Antarctica is often described as a global commons, although competing claims for sovereignty often relegates its status to 'disputed commons' (Joyner, 1998), and Buck (1998) states that an area governed by a regime admitting only a small number of nations should be considered an international commons. The Protocol on Environmental Protection to the Antarctic Treaty in Madrid in 1991 affected the Antarctic regime so that it does have qualities of a global commons (Buck, 1998). The global commons are defined as areas or resources outside the jurisdiction of any nation or group of nations – either belonging to no one or to everyone (Dunoff, 1992; Joyner, 1998). The atmosphere, outer space and deep ocean are the principal models of a global commons;, however, Antarctica avoids traditional designation and crosses both categories of commons, adding to the exclusivity of the continent (Joyner, 1998).

The Fourth Assessment Report (AR4) by the Intergovernmental Panel on Climate Change (IPCC) has identified a lack of continuous data availability on Antarctic climate observations, necessitating an increase in Antarctic science research and data sharing between all nations (Solomon et al., 2007). Antarctic climate research is critical to improving overall understanding of the Earth's climate system, due to the global connectivity of the atmosphere and ocean, and Antarctica's importance in the geotectonic regime (Kennicutt II, 2014). The instrumental period, or the beginning of long time-series scientific observations (measurements before this time were not continuous), began with the International Geophysical Year on July 1st 1957 and initiated Antarctic-specific climate change study which continues today (Turner et al., 2009). The International Geophysical Year was an international science convention that aimed to bridge gaps that the Cold War had created in scientific exchange between the East and West (Turner et al., 2009).

Continuous scientific studies in the southernmost continent began in 1957, and were greatly improved upon with the incorporation of satellite measurements after 1980 (Turner et al., 2009). The IPCC's fifth assessment report (AR5) found that satellite and in situ observations of the Antarctic had improved considerably between the AR4 (in 2007) and the AR5 (in 2013), improving understanding of ice sheet dynamics and drivers, but there is still much to be done (Vaughan et al., 2013).

Prominent research areas of current Antarctic climate science include ozone depletion in the atmosphere over Antarctica, sea level rise, CO_2 sequestration in the Southern Ocean, and changes to the cryosphere – particularly issues of ice shelf and ice sheet mass balance, stability of the ice sheets, and sea ice trends (Solomon et al., 2007). Some examples of these research areas follow here, to demonstrate the importance of Antarctic climate science in determining global impacts of climate change.

Ozone levels at altitudes between 14 and 22 km above Antarctica began to decline in the late 1970s with the extensive injection of CFCs into the atmosphere through industrial activity, destroying virtually all ozone in this altitude range (Turner et al., 2009). Full recovery of the ozone hole over the Antarctic to 1980 levels is expected to occur around 2068 (Newman et al., 2006). The ozone hole maintains cooling within the polar vortex by intensifying circumpolar winds and protecting Antarctica from warming. Research into how Antarctica may warm with the re-emergence of 1980 ozone levels will be closely examined in the coming decades (Solomon et al., 2007).

Sea level rise due to Antarctic ice sheet losses are very likely to have contributed to sea level rise over 1993 to 2003; indeed, the IPCC has quoted sea level rise as 0.21 ± 0.35 mm per year over this time period (Solomon et al., 2007). Flow speed has increased for some Antarctic outlet glaciers (Scambos et al., 2004), indicating that the contribution of Antarctica to global sea level rise may increase in coming years, requiring substantial monitoring.

The Southern Ocean absorbs a substantial amount of atmospheric CO_2 (Turner et al., 2009). Strong westerly winds enforce a mixing regime between surface water and deeper CO_2-rich water, restricting further absorption into the surface water due to carbon dioxide saturation (Turner et al., 2009). This also changes the pH balance in Southern Ocean waters, creating more acidic surface waters with the potential to interrupt the biological pump, which has significant ecological impacts and teleconnections (Maas et al., 2013). A lower pH, through saturation of the upper ocean, has been shown to decrease the calcification rate of calcifying organisms as investigated by Feely et al. (2004). Data regarding the size of the CO_2 sink in the Southern Ocean is relatively sparse, and fluctuations in annual CO_2 levels are unknown (Le Quéré et al., 2008), Additional large-scale monitoring of the Southern Ocean is required.

Ice shelves on both the easterly and westerly margins of the Antarctic Peninsula have begun to retreat in recent decades, changing the cryospheric composition of the surrounding region (Turner et al., 2009). The collapse of the Larsen B ice shelf during February-March, 2002, is a prime example. The reason for the ice shelf collapse has been proposed as a consequence of a record high in air temperature, a long surface melt season and large melt pond extent (Scambos et al., 2000). Subsequent increase in the centreline flow speed of four glaciers adjacent to the remnant ice shelf has been observed as a consequence of the Larsen B disintegration (Scambos et al., 2004). Velocity increases may affect the rate at which sea level rises; therefore, further investigation of these interactions is needed.

Clearly, Antarctic climate research output, including the global connectivity of changes to the Antarctic region under climate change, is compelling – however, there is a lack of global action towards mitigating further releases of greenhouse gases that could cause catastrophic changes to Antarctica and the global climate in the future. In this paper, we investigate current literature to ascertain the state of communication of both of Antarctic climate science and climate science in general, and discuss existing barriers to obtaining public and political support for climate action. We will then examine more effective ways of developing and communicating climate science from Antarctica, including interdisciplinary and boundary work, and conclude with a series of recommendations to gain traction on socio-political aspects of climate change.

Communicating climate science

Excellence in scientific research is no longer the sole focus for climate scientists; it has become vital for researchers to also communicate the validity and importance of their research outcomes to both policymakers and the general public (Fischhoff, 2007; McBean & Hengeveld, 2000). However, this can be challenging for researchers, as communication skills are often absent from early-career science training and tertiary education, and are often not a part of training throughout careers either (Heath et al., 2014; Liggett et al., 2010; Trench & Miller, 2012). There are calls for this to change, arguing that communication not only increases public understanding of academic research, but also increases the value of research itself by highlighting new pathways and gaps in science as well as bridging interdisciplinary divides (Baron, 2010). Furthermore, scientists with training in science communication have been documented as being more likely to engage with the public throughout their careers, rendering the resources and time required to train young scientists in science communication a worthy investment (Royal Society, 2006). It has also been suggested that, rather than focusing solely on training more scientists in communication skills, there should be an emphasis on training non-scientists (for example, business people, lawyers, and politicians) to understand the values of evidence-based debate and refining questions based on evidence (Mole, 2012).

Provencher et al. (2011) suggest that in order to achieve effective communication outcomes, a dedicated Education, Outreach and Communication (EOC) program must be incorporated into research programs. These EOC approaches would use a series of communication methods to identify target audiences and utilise personnel that have been trained in science communication as part of a science strategy to encourage effective communicators to engage further with the community, and to encourage scientists that are not strong communicators to work with teams that already have robust communication and public relations roles (Provencher et al., 2011).

Public trust in science

Scientific research throughout history has largely taken place in academic circles, exclusive of public involvement and outreach, which has resulted in a wide knowledge gap among the general public, and at times, suspicion and scepticism of scholarly work and the academic elite (Brush, 1989; Provencher et al., 2011).

97% of climate scientists are in agreement that human activity is the dominant cause of observed changes to global climate (NASA, 2015); but recent research by the Pew Research Centre (2009) found during a survey of

US citizens that, while approximately 84% of scientists (of all disciplines) accept the science of anthropogenic climate forcing, only 49% of the US public accept it. In the following paragraphs, the subsequent effects of this perceived disciplinary gap are examined by analysing various studies on the public's perception of science, scientists and technology. It is acknowledge that the majority of these are from Western countries; however, no recent studies were found from developing countries for comparison.

In the UK, the most recent study of the general public's attitude towards science found that, of 2000 adults surveyed, 45% agreed that funding to science should be reduced in favour of increased spending elsewhere in the national budget (Castell et al., 2014). The same study discovered that 50% of participants thought of scientists as secretive, while more than one third believed scientists adjusted findings to correspond to their hypothesis. Few participants understood the peer review process, and 30% believed academic work was rarely checked by other scientists prior to publication. Significantly, 60% of participants felt scientists did not make sufficient efforts to communicate their findings, while 70% stated they wished to hear about ethical and social implications of research directly from the scientists.

A similarly high level of interest in science and technology was recorded in a study from Australia, though knowledge of the national scientific research organisation, the CSIRO, reduced from 70% among participants aged 35 and over, to 35% among those aged 18-24, suggesting a significant lack of engagement of major research organisations with youth in Australia (Cormick, 2014). A study in the USA designed to measure scientific knowledge found that approximately 66% of participants do not understand the scientific publication process and that trust in pseudoscience is quite common, with 60% surveyed believing in extrasensory perception and nearly 50% considering astrology a scientifically valid field (NSF, 2004,2014).

In New Zealand, specifically related to Antarctic science, it is a much better situation. It was found that public awareness and support for Antarctic science is very high, with a survey finding that 70% of participants believed Antarctic involvement from the NZ government was at least 'quite' important (Antarctica New Zealand, 2010). From this group it was found that 90% believed that 'protecting the environment in Antarctica' was important, and 87% stating that it was important to help with science. It was also found that the main reason those that thought it was important for the NZ government to be involved with Antarctic science was due to its significance in global climate (48%) and its need to be protected (42%).

Based on the evidence above, other than the positive response to Antarctic science in New Zealand, the general trends of public trust and engagement with science are concerning and pose a major barrier to effective communication of climate science and the need for action. Even in New Zealand, however, as described above there is a considerable lack of understanding or value placed on Antarctica's significance in the global climate, suggesting that there still exists a gap that needs to be addressed.

Another issue that may be hindering the gain of support and trust from policy makers and the public is the notion that science may be diminishing wonder and intruding on humanities, reducing the mystery and ambiguity of the world (Pinker, 2013). For example, the notion of seeing 'beauty' in the world can be explained by reactions of brain chemistry in an individual, rather than spirituality, and that behavioural 'ethics' can be reduced to basic human instinct and natural selection (Pinker, 2013). To expand upon this, science can demonstrate that the supposed empirical basis for some moral values is, quite simply, not factual. For example, Pinker states 'there is no such thing as fate, providence, karma, spells, curses, augury, divine retribution or answered prayers.' While science doesn't necessarily dictate values and beliefs, it can provide the framework (Pinker, 2013). This is supported by Lorenzoni and Pidgeon (2006), who state that trust of an individual is unlikely to be gained if the science does not align with that individual's beliefs, does not affect them personally, and/or if the threat is not immediate and serious.

The lack of trust in climate scientists may also be due to the dependency on technology and unwillingness to change. Most people are aware of their moral obligations towards society with regard to climate change, however most people also recognise their own failings to enact on these obligations (Lorenzoni & Pidgeon, 2006). Another source of this mistrust may be the perceived low salience of climate science; there are persistent misunderstandings about climate change that make implementing and encouraging mitigation methods very difficult (Lorenzoni & Pidgeon, 2006). A more in-depth discussion of this is presented further into this report.

A significant proportion of Antarctic climate research has a propensity towards complex interactions with other areas of climate research. As an example: the ozone hole cannot be treated as an isolated cause-and-effect incident that concerns merely the CFCs trapped within the polar vortex; rather, the maintained cooling of the polar vortex in turn intensifies the circumpolar winds that protects Antarctica from warming but also stimulates surface and deep water Southern Ocean mixing (Blunden et al., 2011) which in turn affects the previously mentioned Southern Ocean acidification. Such complex physical interactions may contribute to the problems faced by climate change science communication that can be plagued by claims of exaggerating risk, sensationalism, "bad" science and incitation of public hysteria (Weingart et al., 2000).

Progress toward mitigating the effects of climate change will only be made if the public is educated about the global interactions between components of the climate system and the consequences of climate change. This could be achieved through communication training for scientists, as discussed previously, and it is widely agreed that research focus and outputs would benefit from this training (Besley & Tanner, 2011).

Where does the general public obtain scientific information?

The media has many outlets for communication of Antarctic and climate science through news reports, press releases, interviews, television shows, blogs and websites. In Australia, for example, visual communication of climate science, such as that presented on television (particularly documentaries and news programs), in newspapers, and on the internet, are the most likely sources of information for the general public (Ashworth et al., 2011; Cormick, 2014). Similarly, 87% of online American adults use the internet to research science topics and 59% of people would turn to the internet for information about climate change, making it a very important resource (Davies & Glasser, 2014; Horrigan, 2006). But the media only reaches a select group of people, those that have access to the internet and TV who are likely to be relatively wealthy, educated, and interested in science (Horrigan, 2006). For example, an analysis of internet traffic on a website about Antarctic glaciers showed that half of the users were in the 22-35-year-old age bracket, and the majority were university students (Davies & Glasser, 2014). Therefore, other demographics are not as exposed to information through this medium. Long-term feedback from surveys of visitors to climate and Antarctic science media is needed to discover how to reach other demographics.

The public can also gain scientific knowledge from other sources such as museums and public lectures. Many scientists already participate in these events, but getting the public interested and involved is still a challenge (Besley & Tanner, 2011). Only 48% of Americans go to a zoo or aquarium at least once a year, 26% have been to a natural history museum, 23% have been to a science or technology museum and 14% have been to a planetarium in the last year (Horrigan, 2006). More research is needed into how these other stakeholders can attract not only higher attendence, but also a wider range of people. Scientific literacy is a critical component in communicating science and enabling to public to make their own decisions based on scientific research, and there is a strong connection between economic development and sustainability with scientific literacy (Provencher et al., 2011).

Misreporting and miscommunication of climate science

As scientists play a crucial role in advising policy, their advice can become a topic of contention in the media, which can lead to their research being misrepresented or miscommunicated (Rapley et al., 2014). The media has a huge influence on public attitude toward climate science, which can have significant consequences (Brulle et al., 2012; Rapley et al., 2014). It can occur in two ways, through media misreporting, and misunderstanding by the audience (Bell, 1994). However, misrepresentation is not a new phenomenon.

Previous global issues such as nuclear weapons, exposure to asbestos and lead, acid rain, the ozone hole, and tobacco have also been subject to misrepresentation (Oreskes & Conway, 2010).

Misrepresentation is a worldwide issue. In 2013, a study was conducted in the USA on the accuracy of cable news segments about climate change and found that while 92% MSNBC segments were accurate, only 70% of climate science-related segments on CNN were accurate and 28% of Fox News Channel segments were accurate (Figure 1) (Huertas & Kriegsman, 2014). 38% of American adults watch cable news, and Fox News is the most popular channel; therefore the lack of accuracy in programs on these channels is a serious problem (Olmstead et al., 2013). Segments that correctly represented findings from climate science were categorised as accurate, and those that contained any inaccurate or misleading representations of climate science were classed as misleading, in accordance with the best available scientific evidence at the time of broadcast (Huertas & Kriegsman, 2014). The majority of misleading news segments on Fox News came from a weekday opinion show called The Five, where famous news personalities discuss current events in the absence of science or industry experts; if not for this show, Fox News would have had an accuracy rating of 45% (Huertas & Kriegsman, 2014).

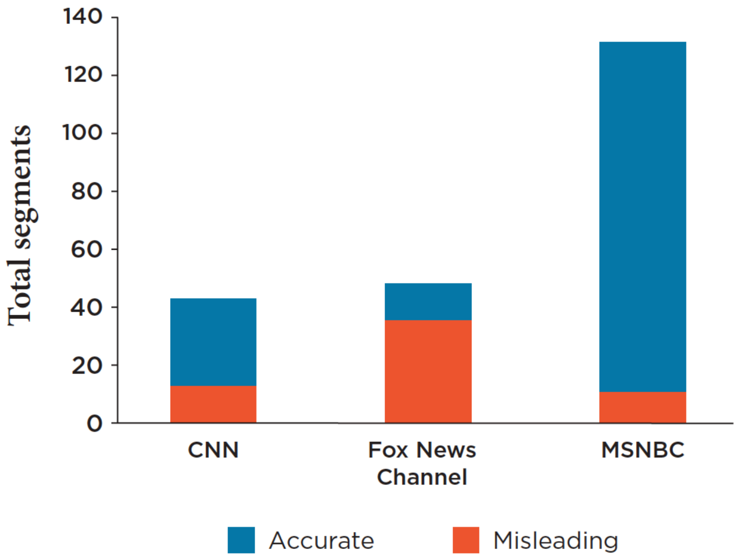

Figure 1: The accuracy of climate-related news segments over the three main cable news networks in the USA (from Huertas & Kriegsman, 2014)

Misrepresentation may be the reason why only two-thirds of Americans accept the science of climate change, and less than half of the population recognise that human activities are the dominant cause (Leiserowitz et al., 2014; Vaughan et al., 2013).

In New Zealand, the situation is slightly better with over 80% of

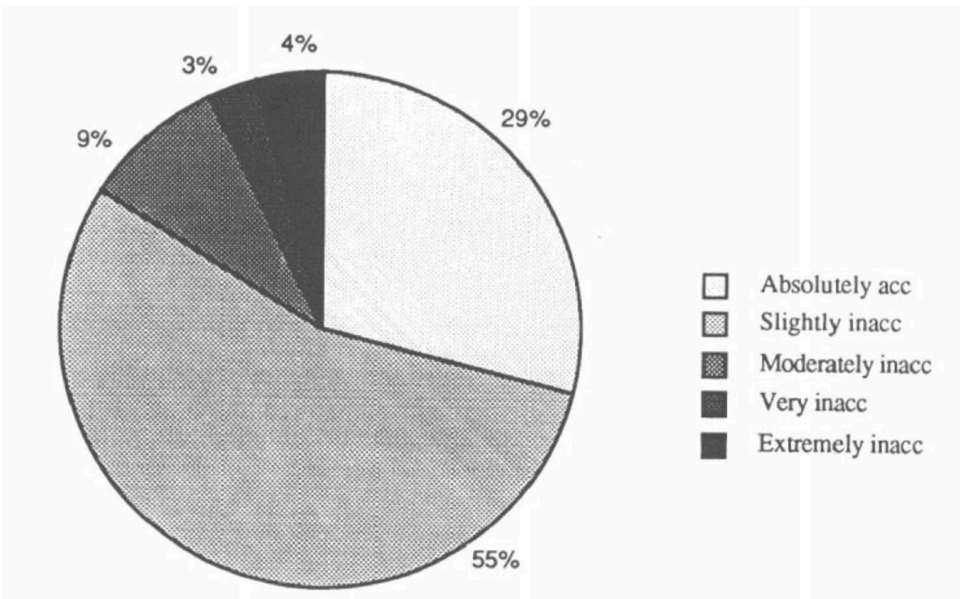

Figure 2: Accuracy ratings of New Zealand climate-related news stories (from Bell, 1994)

stories classified as, at worst, slightly inaccurate (Figure 2); however, one in six reports were significantly inaccurate (Bell, 1994). This study is, of course, significantly older than the 2014 study in the USA, and updated research into the accuracy of media representation in New Zealand would be useful to more precisely compare media representation between different countries – however, Bell (1994) is currently the most recent study available for New Zealand.

In January 2004, Nature published a study by Thomas et al. (2004) that modelled the potential effects of climate change on the distributional ranges of certain groups of land animals and plants, predicting between 15-37% of the 1103 species considered within the study would be 'committed to extinction' by 2050 (not the number of species that will become extinct during this period). This became a global news item that was extensively misrepresented. 21 reports claimed over a million species would go extinct due to global warming by 2050 and only 2 reports explained that only a few species would actually be extinct by 2050 (Ladle et al., 2005). Several reasons for this have been suggested: that perhaps the news reporters did not understand the article; the need for sound bites could have engendered oversimplification; information may have been taken from an indirect source rather than the original source; or the story could have been exaggerated in an effort to sell more newspapers (Ladle et al., 2005).

Another example of misrepresentation was when the U.K. Met Office's Hadley Centre reported that the last decade had seen a sputtering rather than a steady increase in global temperatures. They stated that warming is set to resume quickly and strongly but it resulted in articles such as the BBC News "What Happened to Global Warming?" (Hudson, 2009). A flurry of media activity followed, with broadcasting of many conflicting opinions (Boykoff, 2013), making it difficult for the public to know who to trust or believe.

Scandals have contributed to the misrepresentation of climate science and scientists in the media. For example, in July 2006, ABC News revealed that the Intermountain Rural Electric Association paid $100,000 to climate skeptic Patrick Michaels to downplay mankind's role in climate change and confuse public understanding of anthropogenic climate change (Boykoff, 2013). In 2007, The Guardian newspaper revealed a call from the American Enterprise Institute that "offered payments for articles that emphasise the shortcomings of a report from the UN IPCC (Boykoff, 2013). The climate science scandal of 'Climategate' occurred in 2009, when the email accounts of climate researchers from universities in the UK and USA were hacked, and phrases from personal communications about their work published out of context to paint climate scientists as fraudulent and manipulative, and to cast doubt on the reliability and morality of the peer review process (Grundmann, 2013). Although investigations cleared the scientists of any wrongdoing, significant damage had been done to the public opinion and trust of climate scientists and research (Leiserowitz et al., 2014; Leiserowitz et al., 2013; Maibach et al., 2012)

Subsequently, many climate scientists have avoided engaging with the media about their research, partially out of fear of being misrepresented (Besley & Tanner, 2011; Davies & Glasser, 2014). From a scientist's perspective, there are many causes of misrepresentation, such as oversimplification. Media articles are often considered too simple and short to supply adequate information (Davies & Glasser, 2014). Indeed, approximately 49% of scientists believe media oversimplification was a 'major problem' for 'science in general' (Press, 2009). Oversimplification increases the risk of misrepresentation, and therefore the credibility of the information (Rapley et al., 2014). Scientists also believe that the media is unable to distinguish between good and bad science, and print articles that are not scientifically sound (Besley & Tanner, 2011). Journalists consider it their job to be objective and account for all opinions, and if climate scientists do not cooperate, journalists will get their information from other sources (Boykoff, 2013).

To reduce misrepresentation of climate science and scientists in the media, it is imperative that scientists learn to frame information in a way that is accessible to public, without compromising truth (Bonetta, 2007). Basic facts of articles need to be accurate, and any uncertainties about the information needs to reported (Bell, 1994). Finally, the media needs to play its part in reducing sensationalism to allow people to form their own opinions (Huertas & Kriegsman, 2014).

Political decision-making on climate change

The most significant motivation for governments to commit to action to mitigation climate change is public support and 'license to govern'(Hatfield-Dodds et al., 2007b), despite economic modelling demonstrating that taking leadership to reduce future economic and social risks of climate change is affordable and financially responsible (Hatfield-Dodds et al., 2007a). It is therefore imperative to gain public understanding and support for climate action in order to engender change in political motivations. Here, we discuss some of the barriers to robust climate action, and identify opportunities for obtaining public and political support for mitigation policies.

Spatial and temporal disparity

The timeline during which climate change impacts will come into full force is disparate from the timelines of resource consumption and short-term political action. Thermal inertia in the climate system results in a delay in the response of the climate to alterations in the Earth's radiation balance which, depending on the level of climate sensitivity, could be on a scale of decades to over a century (Hansen et al., 2005). Projections of the disintegration of the West Antarctic ice sheet state that within two centuries, the Thwaites Glacier will likely begin rapid collapse, causing the West Antarctic ice sheet to flood with seawater and eventually disintegrate entirely over the following few centuries (Sumner, 2014). This disassociates the future impacts of climate change with the everyday life of many people alive today, and with a political cycle of 4-5 years in most developed countries, this can act as a disincentive for politicians to commit to long-term strategies of climate action that produce little tangible benefit during the lifetime of the administration (Hale, 2010). Non-governmental actors, such as NGOs and community groups, are vital in diluting this political disincentive in the policy conversation (Hale, 2010).

Similarly, because greenhouse gases disperse into the atmosphere upon emission and spread throughout the globe, there is an increasingly abstract relationship between the consumer of a greenhouse gas emitting resource and the impact of its emission (Purdy, 2010). For example, a study by Leiserowitz (2005) demonstrated that most Americans consider the risks of climate change to be moderate, and will impact distant places and non-human nature at distant times. The same study used the example of framing dangerous climate change on the timescale of the collapse of the West Antarctic Ice Sheet as creating a perception of 'dangerous' as distant, and less urgent – the definition and context of 'dangerous climate change' dictates which solutions will be considered, and on what timescale (Leiserowitz, 2005). Perceived largely as a distant wilderness and scientific laboratory (Tin et al., 2009), Antarctica is arguably also somewhat cognitively disconnected from the everyday consumption of resources by industry and the general public. We argue that it is important to consider the framing aspect of space and time when connecting the science and impacts of climate change in Antarctica to the everyday activities of citizens in distant countries.

Furthermore, the Earth's climate is a complex system with many components that do not change linearly (Feichter et al., 2004). This is an argument that has been co-opted and frequently utilized by proponents of climate change *denialism* in asserting that reducing greenhouse gas emission to prevent catastrophic future changes will have minimal or no tangible outcome in the short-term, and are contentious in the long-term, and therefore adaptation, not mitigation, is a more adequate response to impending changes (Washington, 2013). This is often the argument of those who have much to gain from maintaining the status quo, and often are in positions of influence that enable them impede policy progress and benefit from the resulting inaction (Christoff & Eckersley, 2013).

Frames and worldviews

'Framing' is an individual's (typically unconscious) cognitive structure of words and word systems that is built over time and reinforced in neural circuitry through repeated 'activation', or exposure to information presented in a similar way (Lakoff, 2010). It influences the way in which ideas, issues and concepts are observed and understood, and plays a significant role in the way individuals consider polarising issues such as climate action. Frames are highly dependent on individual worldviews, ideologies, and emotions, and once built, frames can be difficult to alter – even in the face of new, conflicting information or scientific discoveries. This can make it difficult to reconcile contrasting views, as utilisation of particular frames is only useful if it corresponds to an existing 'learned' storyline, or can be linked somehow from an outside position to an existing frame (Nisbet & Scheufele, 2009).

A worldview, or 'ultimate value position', is developed over an individual's lifetime, influenced by a myriad of factors including socio-economic conditions, culture, interactions with family and other individuals, education, exposure to the media, and individual values and experiences (Harding et al., 2009). These worldviews shape how an individual, group, or community identifies with nature and the environment, and can influence their relationships with spatial and temporal disparity, as discussed above ((Purdy, 2010). From a political perspective, the individual and combined worldviews of a government or multilateral group can structure and influence policies and decisions that impact upon these disparities, such as current versus future generations, comfort of citizens of their nation state versus climate impacts on distant countries, and economic analysis of short-term benefit versus long-term detriment (Hedlund-de Witt, 2012; O'Brien & Wolf, 2010). An example in the context of climate change is that of senior decision-makers in government and businesses in the Western world, who have been documented as observing the world through a narrow sphere that prioritises personal reputation, wealth, and competitiveness, and deprioritises the wellbeing of 'others', whether that category be the rest of the world in the present or future generations (Rickards et al., 2014).

Framing climate change science and policy

The manner in which environmental and political issues are framed has significant influence on the supportiveness of the general public of action to mitigation climate change (Hurlstone et al., 2014). Examples include climate as an emergency situation, a pre-emptive frame that calls for action to address the concerns for looming catastrophic climate change, even in the absence of definitive evidence (Markusson et al., 2014). This is particularly common in discourse advocating geoengineering tactics (Eric Bickel, 2013). However, this frame is also seen as unhelpful, with calls for a 'less shrill form of politics' to engender a more deliberative and constructive conversation on climate action (Markusson et al., 2014). Similarly, the common adversarial framing and discrediting opposite sides of the climate science and policy conversation has been detrimental to a considered and thoughtful approach to global action (Knight & Greenberg, 2011).

Discussion of climate policy is often accompanied by the tallying of 'cost' – the difference between living standards growth in a particular country when action is implemented and when it is not; however, this is often misinterpreted by the general public as an overall reduction in living standards over time rather than a slowed growth rate (Hatfield-Dodds & Morrison, 2010). This may reinforce the 'status quo bias', that is, the propensity for individuals to maintain current conditions by forgoing action in order to prevent unknown potential risks or losses in the future (Samuelson & Zeckhauser, 1988). A study in Australia shows that by framing the cost of mitigation action as a 'foregone-gain' rather than an outright loss, the general public tends to be more receptive to higher mitigation targets (Hurlstone et al., 2014). Furthermore, emphasis on large, long-term goals, such as 'an 80% reduction by 2050', has been shown to dissuade the public from supporting action, as it reduces the perception that an individual can make a difference; however, framing climate action in smaller, more attainable goals, such as 'a 2% reduction per year until 2050', provides more motivation for individuals to support collective action (Manning et al., 2009).

A study of university students demonstrates that framing mitigation action in the context of ensuring the safety of citizens and avoiding negative impacts of dangerous climate change is significantly more persuasive than messages which portray the benefits of climate action (Bertolotti & Catellani, 2014). Research by Dickinson et al. (2013) shows that climate change messages are also very effective when they concern an 'object' that appeals to the individual, such as the dangers inherent for animals under climate change.

Effective communication of climate science to the general public therefore relies on the ability of scientists and communicators to frame issues in a way that relates to the worldviews and values of the general public, to engage and translate knowledge and urgency appropriately (Groffman et al., 2010). A key approach is that of the 'meta-narrative', in which multiple, coordinated messages (or narratives) of climate science information are delivered in an engaging, harmonious and coherent manner, allowing all parties (including the general public) to connect to the different areas and perspectives of climate science and understand the limitations of scientific certainty and capacity (Rapley et al., 2014).

Climate change, politics and religion

Political leaning and religion can act as substantial barriers to action on climate change. Religious beliefs tend to guide individual engagement with nature and the environment, and vary widely between different religions and political leanings (Haluza-DeLay, 2014). In the USA, for example, there has been a noticeable trend in recent decades in conservative politicians moving away ideologically from environmentalism and climate change action, promoting sceptical views on the validity of not only climate science, but of the theory of evolution as well (Dunlap & McCright, 2008). These conservative values often correspond with religious leanings, with conservatives in the USA often associated with evangelical Christianity and strong beliefs of creationism (and the accompanying suspicion of scientists promoting evolutionary theory) (Haluza-DeLay, 2014). Several narratives have been identified from Christianity in the USA as to a relationship with nature and the associated perspective on climate change, ranging from views of environmental stewardship, to ideas of taming the wilderness to become God's garden, or that progress and change in God's garden should be encouraged (Wardekker et al., 2009). A survey by Reddy et al. (2013) found that over 50% of participants from South Africa, 66% of participants from India, and 50% of surveyed Americans believe that policymakers depend too much on science and not enough of faith. In order to bridge this divide between faith and scientific reasoning, it is vital to remove the perspective that science and faith are mutually exclusive. For example, one potential solution could be reframing climate science to more easily co-exist with religious frameworks, and more easily appeal to moral and ethical values of environmental and planetary stewardship that are common between many religions and political views (Wilson, 2006).

The role of scientists in climate policy

Pure, basic scientific research has possessed perceived superiority over applied research since the time of the Greeks, and over the centuries has developed into a 'linear' model of innovation (Godin, 2006). In the linear model, basic research progresses to applied research and development, before advancing and concluding with diffusion into society and the economy (Godin, 2006). It has been argued that the simplicity of the linear model makes it useful at the interface of science and policy, as dealing with completely interconnected systems is, by contrast, significantly more complicated (Balconi et al., 2010). However, in terms of climate policy, the linear model is considered inferior to the 'co-production model', a collaborative, interdisciplinary approach incorporating scientists, policymakers, members of industry and other experts, and the general public (Rapley et al., 2014). To function as part of the co-production model, Pielke (2007) argues that scientists must adopt one of four idealized roles: the pure scientist, the science arbiter, the issue advocate, or the honest broker, which are further described in Figure 3.

Pielke (2007) proposes that with issues such as climate change where moderate or high uncertainty exists in outcomes, and where values are conflicting, each of the roles (though particularly those of pure scientist and science arbiter) runs the risk of 'stealth issue advocacy', where a scientist may unconsciously or deliberately promote an outcome while appearing to focus only on the science. All four roles are necessary to the development of climate policy, though the role of the honest broker is often considered the most useful for the co-productive model (Pielke, 2007; Rapley et al., 2014).

1. **Pure Scientist – producing scientific knowledge and information, focused on contributing to a discipline's knowledge repository with little or no interactions with the policy and decision-making end-user;**
2. **Science Arbiter – responding to factual questions that decision-makers may have of the science, while avoiding policy discussions and working to eliminate options that are not adequately supported by scientific evidence;**
3. **Issue Advocate – actively participating in policy-making processes, guiding discussions towards a particular course of action that is supported by scientific evidence;**
4. **Honest Broker – actively participating in policy-making processes, conveying the full scope of options available to policy decision-makers and clarifying the strengths and weaknesses of all options.**

Figure 3: The four idealised roles for scientists in a co-productive model (summarised from Pielke [2007])

Boundary organisations in climate science

A significant disciplinary divide between climate scientists and policy-makers is perception of disciplinary dominance: policy-makers tend to see their work as 'on top' and that scientists are a resource to call upon when required, whereas scientists view their role as objective knowledge transfer that provides expert judgement to people in power (Hoppe et al., 2013). It has been suggested that boundary organisations, which provide 'boundary work' such as assessment of scientific work in conjunction with design of policy instruments and impacts, could hold the key to bridging the disciplinary divide science and policy (Hoppe et al., 2013). The purpose of a boundary organisation is to 'facilitate collaboration and information flow between the research and public policy communities' (Parker & Crona, 2012). Boundary organisations in climate science and policy already exist; one well-known example being the Intergovernmental Panel on Climate Change (IPCC).

Although it enjoyed an excellent reputation during the early years of its existence, more recently, the IPCC has been subjected to criticism about its methods and output. For example, the exhaustive, 900-page reports require a lengthy production process, and often areas of the science are out-of-date by the time the report reaches publication (Nature, 2013). This has prompted questions within the science community as to whether the IPCC should continue to produce large-scale reports into the future, when much of the science is no longer 'new', or whether areas of climate science should be broken into smaller, more targeted reports (such as the recent Special Report on Climate Extremes) to focus on areas that have high uncertainty, where knowledge can evolve more quickly, and/or are areas of particular political import (Nature, 2013). There have been calls to reform the IPCC's roots in the linear model of innovation, using the 'linear knowledge production' theory that more research will lead to more certainty and better policy outcomes, advising policy-makers in a one-way conversation (Beck, 2011). It has also been argued that the IPCC has a monopoly on the transfer of climate science information to advise international policy-makers, and that over time, without competition, the IPCC's quality has declined and has engaged in tasks beyond its mandate (Tol, 2011). Critics suggest that it would be beneficial for climate science and policy alike to establish other boundary organisations, specialised in particular climate science aspects, to provide competition and encourage development in particular aspects (Tol, 2011).

Many aspects of Antarctic climate science have high levels of uncertainty, and scientific understanding of the dynamics and drivers in many parts of the climate system have the capacity to evolve very quickly. Furthermore, the potential impacts of Antarctic climate change are of global significance. In 1957, these factors led to the establishment of the Scientific Committee on Antarctic Research (SCAR), an interdisciplinary committee as part of the International Council for Science (ICSU) with the research objective of 'initiating, developing and coordinating high quality international scientific research in the Antarctic region (including the Southern Ocean), and on the role of the Antarctic region in the Earth system' (SCAR, 2015a). SCAR also plays a role in advising policy for the Antarctic Treaty Consultative Meetings, and providing expert advice to international organisations such as the IPCC on conservation and management of Antarctica as well as Antarctica's role in the Earth's climate system. However, although SCAR is a highly regarded source of research and policy advice on Antarctic climate science, it does not specifically address the communication of how impacts of climate change on Antarctica impact on the rest of the world – the 'global teleconnections' of Antarctica (Kennicutt II, 2014). Therefore, we argue that there is a need for the establishment of a sub-committee within SCAR producing boundary work integrating Antarctic climate specialists and other scientists with international policy experts and other relevant stakeholders in a co-production model of knowledge exchange and interdisciplinary research to improve the translation of research output into the community and policy domain, and to engender public support for robust climate action.

Gaining traction on climate change

A contemporary standing committee

The Scientific Committee on Antarctic Research engages a collection of sub-committees as advisories to its secretariat, a permanent administrative department of SCAR. Figure 4 illustrates the organisational structure utilised by SCAR as of December 2014.

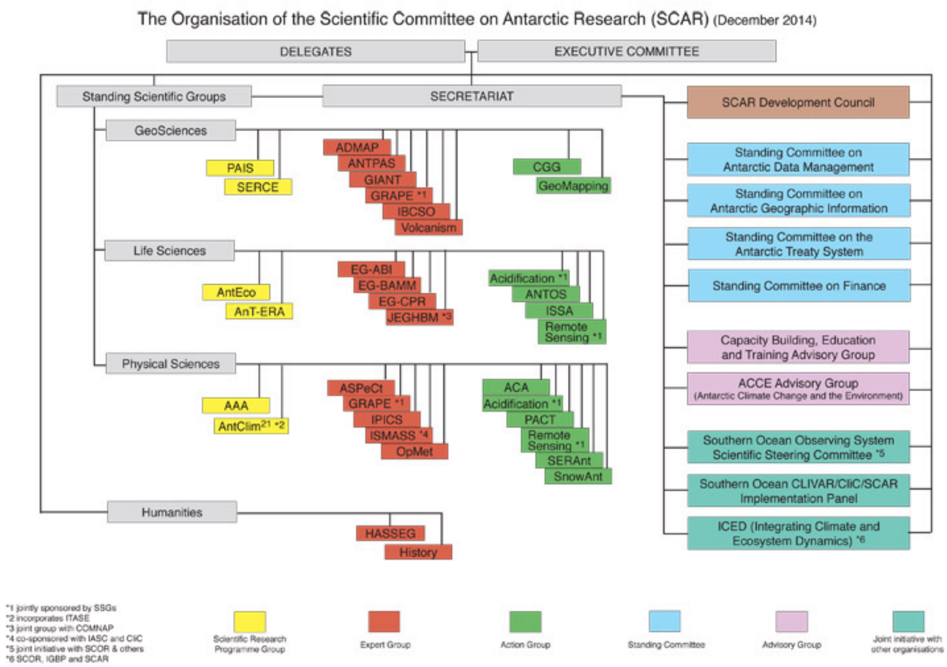

Figure 4: An overview of SCAR as at December 2014 (SCAR, 2015b). The proposed standing committee would be subordinate to the secretariat.

An additional standing committee of permanent residence within the SCAR organisation given jurisdiction over the production of transparent boundary work aimed at bridging the gap between research output, policy, and the communication of these results to the diverse intellectual gradient of the public domain would provide physical proof of SCAR's commitment to its fifth mission objective, *to communicate scientific information about the Antarctic region to the public* (ICSU, 2015). A standing committee dedicated to the rendition of scientific research to the community and policy domain requires a disparate assemblage of Antarctic science experts, physical sciences experts, social science experts, relevantly experienced policy makers, NGO representatives and wider education specialists. Such a specialised group would require significant and ultimately unnecessary amounts of coordination to begin anew. Experts in Antarctic science and other pertinent disciplines are abundantly represented throughout SCAR; the vice presidents who constitute the majority of the executive committee themselves stem the diverse academic specialties of marine biology, geology and meteorology. A diversion of SCAR's existing intellectual resources into the Antarctic science communication standing committee, complemented by small capital expenditure would fashion the foundations for more effective communication on the societal-political aspects of climate change. A new sub-committee aimed at conveying Antarctic knowledge would face the corresponding modern challenges associated with the public's often sceptical and cynical opinions (Baron, 2010) in addition to the fore-mentioned adversarial framing and discreditation of opposite sides in popular climate science and policy debates (Knight & Greenberg, 2011). In order for the proposed standing committee to prosper and provide effective scientific finding communication a strong education, outreach and communication (EOC) agenda is required to build upon the knowledge rich anthropological foundation (Provencher et al., 2011). The EOC program for SCAR's new standing committee would vehemently incorporate the four recommendations made by Provencher et al. (2011) for science outreach programs with astute focus upon the second recommendation, where scientists who are good communicators are given an enhanced role and encouraged to undertake EOC. Scientists who do not communication in a fluent and natural manner would be partnered with bodies that have robust EOC strategies. Neural framing appears recurrently throughout the general public's assessments of climate change and establishes a necessity for project leaders and individuals in significant research roles to be engaged in the EOC strategy, most importantly, the outreach or informal education component (Provencher et al., 2011). Compulsory participation in outreach would compel the thought process of how this research could be conveyed to diverse intelect levels throughout the experimentation process, even factoring into how the research is conducted. Besley & Tanner (2011) indicate that some communication scholars see condescending undertones when the scientific community interacts with the public and a move by SCAR to incorporate project leaders into the outreach component may mitigate this occasional disdainment.

SCAR is the most logical professional body, as opposed to organisations such as the United Nations, to accommodate a standing committee dedicated to the unification of climate scientists, general public, policy makers and relevant stakeholders. SCAR already possesses the intellectual resources required to produce objective science and needs only to train non-scientists in evidence based reasoning. SCAR's fifth mission objective and its aim to be the leading independent organisation for facilitating and coordinating Antarctic research make SCAR the only choice for this Antarctic science communication sub-committee.

A diversion of resources within SCAR to form the new standing committee for the translation of research output into the community and policy domain to engender public support for robust climate action prevails to be the most advantageous use of the association, a textbook case for boundary organisations achievement.

Interdisciplinarity

Interdisciplinarity is not currently commonplace in climate research (Bjurström & Polk, 2011). To achieve optimal co-production research and policy in climate science, interdisciplinarity must be encouraged and promoted. A significant barrier to interdisciplinarity in climate research is the use of different 'languages', requiring substantial investment of time and effort to establish shared vocabularies and ontologies (Bracken & Oughton, 2006). This will be vital to the effective integration of disciplines in Antarctic climate science, where a shared understanding of temporal and spatial perspectives, language differences, and jargon must be developed. Some general principles have been suggested for effective interdisciplinary research that can be applied to integrated Antarctic climate research and policy (Dovers, 2005):

- Problem focus – the shared problems of climate change, communication and translation of knowledge to both policy-makers and the general public, and eliciting effective action as a result, all act as an external position for assessing research output. This is also useful to determine the required skills and perspectives at preparatory stages of boundary work;
- Alertness – remaining aware of agendas and policy objectives that may become dominant;
- Evaluation and reflexive capacity – continually assessing the integrative initiatives of the boundary work and ensuring these needs are being met;
- Openness – welcoming new theories, disciplines, methods, ideas, and knowledge systems to broaden potential approaches and prevent stagnation in a single integrative approach;
- Intra-disciplinary variation – embracing different perspectives, methods and ideas from within individual disciplines;
- Systems orientation – conceptualising basic systems concepts to highlight interconnections between disciplines;
- Scale awareness – appreciating differences in spatial and temporal differences between disciplines and situations; and
- Personal and group qualities – ensuring appropriate group dynamics for effective boundary interactions.

As well as incorporating the above principles, integrated boundary work requires the consideration of different and changeable boundaries and norms within the science policy environment, which are often indefinable, diverse, or even contestable (Head, 2008). Lastly, the scope of the boundary work must be clearly defined, to ensure that the focus remains on interdisciplinary interactions for climate science and communication, and not the transition to multidisciplinary research where the addition of non-shared languages and norms could result in a lack of integration in research output (Bjurström & Polk, 2011).

Conclusions

Although a substantial effort has been made to improve the communication of Antarctic climate science and climate science generally, there is clearly room for improvement. Recent statistics show that public education on climate science is lacking, and that public mistrust in science (reinforced by misrepresentation of climate science and scientists in the media) is creating barriers for effective communication. That the climate action message is not getting through is due partly to it not being framed effectively, and needs to be reconsidered to find common ground between competing worldviews, values, and religious beliefs. Framing of space and time in relation to climate change and Antarctica also needs to be reassessed, to reduce the perceived disparity between the general public and the impacts of climate change. One way to achieve this is a concerted training campaign, for both scientists and non-scientists, to broaden understanding of evidence-based debate among these players in the science-policy environment. Another highly effective strategy is to establish boundary work, integrating interdisciplinary research with education, outreach and communication plans. The role of scientists in these boundary organisations or committees is of paramount importance, as it determines the breadth of the scope of policy options available to decision-makers. Furthermore, it is essential to ensure the integration of research and policy throughout the duration of the boundary work, preventing the division of scientific work as concluding at the publication stage and decision-making to commence at the conclusion of the scientific work.

We recommend the establishment of a targeted boundary committee tasked with compiling, framing and communicating both Antarctic climate science and its global teleconnections to the general public, policymakers and other stakeholders. The proposed committee would act as a sub-committee to the Scientific Committee on Antarctic Research (SCAR), and utilise diversion of SCAR's existing intellectual resources as well as the acquisition of additional funding. Education, Outreach and Communication (EOC) strategies would be a consistent theme in all levels of boundary work of the sub-committee, to improve engagement of Antarctic science and climate science more generally with the public and policy stakeholders. By engaging and educating these stakeholders on the urgency and relevance of Antarctic climate science, traction on robust climate action globally is more likely to be obtained.

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